(For the Association of Professional Engineers of New Brunswick, 1962, January 26) Brunswick Hotel : 1.00 PM

THE REVOLUTION IN ASTRONOMY

Astronomy, at present, is not only rapidly evolving, like the other sciences, it is also undergoing a revolution,-- it is passing from being an entirely observational science, to being, in part, an experimental science.

The revolution is a consequence, not only of the rapid progress of the science, but also of a consequent change of emphasis.

The rapid rate of change, the change of emphasis, and the revolution ~~is~~ are, perhaps, no where so remarkable as in the astronomy of comets.

For centuries, comets were objects of popular superstition. They did not become recognised astronomical phenomena until Halley got the notion that some of the comets seen, might have been the same one returning, and then, ~~with the aid of Newton's as yet unpublished principles of gravitation,~~ established the fact that the comet of 1682 ~~had a period of about 75 and 1/2 years.~~ travelled in an elliptical orbit and would return in about 75½ years.

For a century after the first return of Halley's comet, the chief interest of astronomers was in ~~determing~~ determining the orbits of comets. Then, in the nineteenth century, came spectroscopy, which enabled us to get some idea as to the nature of a comet.

In the twentieth century, the building of large telescopes shifted the interest of astronomers to distant galaxies, and the question of the extent of the universe. A re-awakening of interest in comets came in the year 1955, when the launching of ~~International Geophysical Year,~~ and satellites, ~~were~~ was being planned. The fact that the space between the planets was traversed ~~by~~, not only by comets, but also by material left behind by comets, became of vital importance.

A complete survey of outer space, should include a charting of the paths of comets and of all comet dust revolving in orbits about the sun. Before we set out for Mars, we should know what we are likely to meet on the way. I can envisage the day when an accident will occur to a spaceship, and the finding of the investigating board will be that the ship went off course and got some comet dust in the fuel tank.

The computation of the orbit of a comet, (together with the perturbations which it might suffer from planets as its journeys through space,) used to be a long and tedious operation. When I was a student, there were assistants in observatories who did nothing else but compute the orbits of the comets of the current year. If six comets appeared in a year, that was enough to keep them busy.

You can imagine what a task it would be to work out all the orbits of all the comets ever seen since the beginning of history. That was a task which J. G. Galle, a German, set himself. Galle had, in 1840, discovered 3 comets, and

in 1846, the planet Neptune. He, more than any one else of his time, appreciated what a ~~comfort~~ help it would be to have a catalogue of cometary orbits, so that when a comet was detected we might be able to know whether it was a new one or an old one returning — or a new planet. Not all the comets ever seen in early days, were observed with sufficient accuracy to permit the computation of their orbits. But Galle found 414 which had been seen since the year 372 B. C. whose orbits could be worked out. He was thirty-four years of age when he started to make his catalogue. He finished it when he was 84. (I may add that he was then in about the prime of his life. He died when he was 98).

In 1955, at a meeting of the International Astronomical Union (at Dublin) the British Astronomical Association suggested that Galle's catalogue be re-done and brought up to date, with the computation of all orbits of all comets being run off on the same electronic computer. (Here I may mention that astronomers were among the first great customers of computer manufacturers. At the time of the 1955 meeting of the International Astronomical Union, all the ~~big~~ larger observatories had their electronic computers).

The British Astronomical Association was given a grant to do the work which it suggested. The astronomers who were given the task of supplying the data held up the work. They became very meticulous. They checked all the sources used by Galle, and also sought out the best observations of modern comets. Even with this delay, the catalogue was

published in June, 1961. It contained 830 orbits, of which 264 are of comets which returned, and the other 566 are of distinct individual comets seen between 240 B. C. and 1960 (inclusive),- some of these have not yet returned; the others are not expected to return.

While the new catalogue was being made, interest in comets grew, and more emphasis was put on their study. With improved instrumentation sufficient data has now been gathered to form a ~~pretty generally accepted~~ which is pretty generally accepted, theory as to the nature of comets, and experiments are being planned to verify it.

The nature of a comet is, perhaps, best understood by considering its state when it is far out in space.

Halley's comet is, at present, about 3,000 million miles away from us. Out there, it ~~It~~ is very cold, ~~out there~~. If we could see the comet now, it would look like a very small planet. But its crust is not rocks like the crust of the earth, it is ice. The ice is rough; and it is dirty; it is dirty from meteroic dust picked up in space, when the comet surface was liquid.

As a comet approaches the sun, it starts to feel the heat of the sun. Its crust melts, turns to liquid and then to gas. All this happens before the comet is close enough for us to see it. When a comet is first detected by us, (if it is discovered when coming in,) it looks like a fuzzy star, or a star out of focus. This is due to the foggy envelope, or atmosphere, formed by the gases.

The gases are mainly, methane, ammonia, cyanogen, carbon monoxide and water vapour. As the comet comes closer to the sun, the molecules of the gases are dissociated - by x-ray radiation from the sun - into molecular and ionic radicals. Then, and only then, the comet starts to develope a tail. The tail grows in length as the comet approaches the sun. It is found to consist chiefly of ions with some dust intermingled.

An early as the year 1531, Peter Apian, (Professor at Igolstadt, Bavaria) called attention to the fact that comets always have their tails turned away from the sun. This means that if you see a comet in the western sky, just after sunset, the tail points towards the east, away from the sun. A comet seen before sunrise, in the eastern sky, has its tail streaming across the sky towards the west.

A dramatic and spectacular observation of this fact was made last July by the navigator of a Jet flying from Honolulu to Portland, at a height of about 30,000 feet. The plane was heading east. When facing east, if one watches for some time, one can notice stars rising, as does the sun. When travelling about 700 miles an hour towards the east, the stars seem to rise very rapidly. On the morning of Sunday, July 23, 1961, A. S. Wilson, the navigator, saw a faint whisp of light rising on the eastern horizon. It looked like the light from a distant searchlight. As it rose, Wilson noticed that it narrowed. Finally, it ended,

in the head of a comet. This all happened at about 4:30 a. m., local time. When he landed at Portland, at about 6 a. m., daylight had come. Nobody on the ground had noticed the comet. He proceeded to his home in Seattle. There, also, he failed to ~~Still he did not~~ find anyone who had seen the comet. He sent a telegram to Harvard University Observartory, which spread the news of the discovery. The following morning the comet ~~it~~ was seen, and photographed, by astronomers.

The tail of a comet, when there is a tail, is not something static. It is a stream of particles. The stream fans out, getting wider, and more tenuous, as it recedes from the head of the comet. When we say that the tail is so long, we mean that as much of the tail as we see is so long. Almost certainly it is longer, but so tenuous at the end that we cannot see it. When the source supplying the tail dries up, all the tail gradually streams off into the tenuous invisible state, and orbits round the sun on the same path as the comet. Some comets have crossed the earth's orbit, andwhere they have done so, we run into material left behind, and see what we call a shower of meteors.

From the eighteenth century, until the time of the Second World War, it was generally believed that the tail of a comet was driven backwards by the radiation pressure from the sun. Since, 1945, largely through observations from rockets, our knowledge of the sun's radiation has increased. The pressure of this radiation is now known rather exactly. Before the balloon satellite, Echo, was launched, the amount that it might be forced downwards by

pressure from the sun was estimated. The estimates were good. When we are nearest to the sun, the satellite decends, and when we recede, it rises again. The effect agrees closely with that predicted.

It is now estimated that the sun's pressure, alone is insufficient to account for the ~~long~~ rate at which the tail of a comet lengthens. The fact that the tail starts to appear almost simultaneously with the appearance of numerous ions in the comets head, suggests that the dissocciation processes are the source of power, - but the mechanism is not known.

As the comet recedes from us, the tail shortens. If followed by a large telescope, the comet may be seen going away without any tail. But it still has a large gaseous envelope. Presumably, as it goes further away, the gases liquify and solidify, and the comet continues its icy voyage through space, - and leaves us with a nice tidy theory as to its nature and general behaviour.

We would like to know if our theory about the nature of comets is true. And would-be-space travellers would like very much to have experimental verification of our theories, before they venture into interplanetary space. Consequently, experiments are being planned.

Last August, ~~there was an international assembly of astronomers~~ the International Astronomical Union assembled at Berkeley (California). The Belgian delegation came with a proposal. The Belgians suggested that the United States should launch a rocket, and shoot it right at a comet, -

preferably to go right through the comet's gaseous envelope. They suggested that this be done in 1964, when Comet Encke will be close to us. They suggested that the rocket might carry, besides other instruments, a TV camera, to give us, live, close-up photos of the comet.

At the meeting at which the Belgian proposal was made, there was present the head of the astronomical division of the National Aeronautics and Space Administration, Dr. Nancy Romans. She said that she would be glad to put the proposal before her board. But, she told us, that the National Aeronautics and Space Administration had already given thought to how they might try to verify our theories about comets, and they were talking of making a comet.

Dr. Roman's recipe for making a comet is this: solidify methane, ammonia, cyanogen, carbon monoxide, water, and add a few other ingredients. Put them in a rocket which is a refrigerator. Shoot off the rocket towards the sun, and when it is in orbit around the sun, press a button that will eject the dirty-ice comet. Then watch and see if the molecules dissociate, and if it grows a tail, and if its spectra resembles that of a natural comet.

With this analytic experiment of the Belgians and the synthetic experiment of the Americans, the astronomers are adopting the experimental method of Chemists and Physicists. We have come a long way since comets were blazing stars, threatening the world with famine, plague and war.